

Claims

- 1 1. A method of modifying a virtual object stored within a computer, the method comprising the  
2 steps of:  
3       representing a virtual object as a volumetric model;  
4       converting a subset of the volumetric model into an alternative representation;  
5       determining a response of the alternative representation to a stimulus; and  
6       modifying the volumetric representation so as to substantially represent the response of  
7       the alternative representation to the stimulus.
- 1 2. The method of claim 1, wherein determining a response of the alternative representation  
2 to a stimulus comprises determining a response of the alternative representation to a first  
3 stimulus and further determining a response of the alternative representation to a second  
4 succeeding stimulus.
- 1 3. The method of claim 1, wherein modifying the volumetric representation comprises a  
2 change in shape of the volumetric representation.
- 1 4. The method of claim 1, wherein modifying the volumetric representation comprises  
2 converting the response of the alternative representation to the stimulus into a response of the  
3 volumetric representation to the stimulus.
- 1 5. The method of claim 1, wherein the subset of the volumetric model is the entire  
2 volumetric model.
- 1 6. The method of claim 1, wherein the subset of the volumetric model is a portion of the  
2 volumetric model.
- 1 7. The method of claim 1, wherein the volumetric model comprises voxels.

- 1 8. The method of claim 1, wherein the volumetric model comprises values spaced in a three-  
2 dimensional grid.
- 1 9. The method of claim 1, wherein the alternative representation comprises a surface  
2 representation.
- 1 10. The method of claim 1, wherein the alternative representation comprises a set-of-triangles  
2 representation.
- 1 11. The method of claim 10, wherein the stimulus comprises a weighted displacement  
2 function defined on vertices of the set-of-triangles representation.
- 1 12. The method of claim 1, wherein the alternative representation comprises a selected one of  
2 a polygon set, a bezier surface, a b-spline surface, a procedural surface, and a NURBS  
3 representation.
- 1 13. The method of claim 1, wherein the alternative representation comprises an alternative  
2 voxel representation.
- 1 14. The method of claim 1, wherein the stimulus is a stimulus from a user using a haptic  
2 interface.
- 1 15. The method of claim 14, wherein the haptic interface is a force feedback interface.
- 1 16. The method of claim 14, wherein the haptic interface has at least three degrees of force  
2 feedback.
- 1 17. The method of claim 1, further comprising the step of displaying the virtual object on a  
2 computer display.

- 1 18. The method of claim 1, wherein the volumetric representation and the alternative  
2 representation comprise representations having different numbers of dimensions.
- 1 19. The method of claim 1, wherein the applied stimulus comprises at least one of a  
2 displacement function, a smoothing function, a warping function, a volumetric interference, an  
3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a  
4 force.
- 1 20. The method of claim 1, wherein the applied stimulus is applied to the object in real time.
- 1 21. The method of claim 1, further comprising the steps of:  
2 transforming the alternative representation into a third representation;  
3 modifying the third representation in response to an applied stimulus; and  
4 transforming the modified third representation to a modified volumetric representation.
- 1 22. The method of claim 21, wherein transforming the modified third representation to the  
2 modified volumetric representation comprises generating an intermediate modified  
3 representation.
- 1 23. The method of claim 1, wherein the stimulus comprises a user motion in the at least  
2 three-dimensional space.
- 1 24. The method of claim 1, further comprising applying a feedback force to a user, the  
2 feedback force being generally consistent with a geometric shape of a modified virtual object.
- 1 25. A method of modifying a volumetric representation of an object, the method comprising  
2 the steps of:  
3 transforming at least a portion of the volumetric representation into a polygonal set  
4 representation;  
5 modifying the polygonal set representation; and

6 modifying the volumetric representation to substantially represent the modification made  
7 to the polygonal set representation.

1 26. The method of claim 25, wherein the modification comprises a selected one of a  
2 displacement function, a smoothing function, a warping function, a volumetric interference, an  
3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a  
4 force.

1 27. A method of modifying a volumetric representation of an object, the method comprising  
2 the steps of:  
3 transforming at least a portion of the volumetric representation into a surface-based  
4 representation;  
5 modifying the surface-based representation; and  
6 modifying the volumetric representation to substantially represent the modification made  
7 to the surface based representation.

1 28. A system for modifying a virtual object stored within a computer, the system comprising:  
2 a representation module that represents a virtual object as a volumetric model;  
3 a conversion module that converts a subset of the volumetric model into an alternative  
4 representation;  
5 an analytic module that determines a response of the alternative representation to a  
6 stimulus; and  
7 a modification module that modifies the volumetric representation so as to substantially  
8 represent the response of the alternative representation to the stimulus.

1 29. The system of claim 28, wherein the analytic module that determines a response of the  
2 alternative representation to a stimulus comprises an analytic module that determines a response  
3 of the alternative representation to a first stimulus and further determines a response of the  
4 alternative representation to a second succeeding stimulus.

1 30. The system of claim 28, wherein the modification module that modifies the volumetric  
2 representation comprises a modification module that changes a shape of the volumetric  
3 representation.

1 31. The system of claim 28, wherein the modification module that modifies the volumetric  
2 representation comprises a modification module that converts the response of the alternative  
3 representation to the stimulus into a response of the volumetric representation to the stimulus.

1 32. The system of claim 28, wherein the subset of the volumetric model is the entire  
2 volumetric model.

1 33. The system of claim 28, wherein the subset of the volumetric model is a portion of the  
2 volumetric model.

1 34. The system of claim 28, wherein the volumetric model comprises voxels.

1 35. The system of claim 28, wherein the volumetric model comprises values spaced in a  
2 three-dimensional grid.

1 36. The system of claim 28, wherein the alternative representation comprises a surface  
2 representation.

1 37. The system of claim 28, wherein the alternative representation comprises a set-of-  
2 triangles representation.

1 38. The system of claim 37, wherein the stimulus comprises a weighted displacement  
2 function defined on vertices of the set-of-triangles representation.

1 39. The system of claim 28, wherein the alternative representation comprises a selected one  
2 of a polygon set, a bezier surface, a b-spline surface, a procedural surface, and a NURBS  
3 representation.

1 40. The system of claim 28, wherein the alternative representation comprises an alternative  
2 voxel representation.

1 41. The system of claim 28, wherein the stimulus is a stimulus from a user using a haptic  
2 interface.

1 42. The system of claim 41, wherein the haptic interface is a force feedback interface.

1 43. The system of claim 41, wherein the haptic interface has at least three degrees of force  
2 feedback.

1 44. The system of claim 28, further comprising a display module that displays the virtual  
2 object on a computer display.

1 45. The system of claim 28, wherein the volumetric representation and the alternative  
2 representation comprise representations having different numbers of dimensions.

1 46. The system of claim 28, wherein the applied stimulus comprises at least one of a  
2 displacement function, a smoothing function, a warping function, a volumetric interference, an  
3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a  
4 force.

1 47. The system of claim 28, wherein the applied stimulus is applied to the object in real time.

1 48. The system of claim 28, further comprising:

2 a second transformation module that transforms the alternative representation into a third  
3 representation;  
4 a third modification module that modifies the third representation in response to an  
5 applied stimulus; and  
6 a third transformation module that transforms the modified third representation to a  
7 modified volumetric representation.

1 49. The system of claim 48, wherein the third transformation module that transforms the  
2 modified third representation to the modified volumetric representation comprises a  
3 transformation module that generates an intermediate modified representation.

1 50. The system of claim 48, wherein at least two of the first, second and third modification  
2 modules are the same module.

1 51. The system of claim 48, wherein at least two of the first, second and third transformation  
2 modules are the same module.

1 52. The system of claim 28, wherein the stimulus comprises a user motion in the at least  
2 three-dimensional space.

1 53. The system of claim 28, further comprising a force feedback module that applies a  
2 feedback force to a user, the feedback force being generally consistent with a geometric shape of  
3 a modified virtual object.

1 54. A system of modifying a volumetric representation of an object, the system comprising:  
2 a transformation module that transforms at least a portion of the volumetric representation  
3 into a polygonal set representation;  
4 a first modification module that modifies the polygonal set representation; and  
5 a second modification module that modifies the volumetric representation to substantially  
6 represent the modification made to the polygonal set representation.

1 55. The system of claim 54, wherein a selected one of the modification of the polygonal set  
2 representation and the modification of the volumetric representation comprises a selected one of  
3 a displacement function, a smoothing function, a warping function, a volumetric interference, an  
4 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a  
5 force.

1 56. A system of modifying a volumetric representation of an object, the system comprising:  
2 a transformation module that transforms at least a portion of the volumetric representation  
3 into a surface-based representation;  
4 a first modification module that modifies the surface-based representation; and  
5 a second modification module that modifies the volumetric representation to substantially  
represent the modification made to the surface based representation.